Effects of Substrate Interactions on In-plane and Out-of-plane Order in Thin Films of Lamellar Copolymers

Gila Stein
University of Houston

Thin films of lamellar copolymers can assemble into well-oriented perpendicular domains when confined between two ``neutral'' interfaces, and controlling this behavior is critical for applications in semiconductor lithography. We examined the ordering of poly(styrene-b-methyl methacrylate) (PS-PMMA) lamellar copolymers confined between a neutral free surface and a ``nearly neutral'' brushed poly(styrene-r-methyl methacrylate) silicon substrate. The PS-PMMA film thickness (t) and brush grafting density (Σ) were systematically varied to examine their impacts on in-plane and out-of-plane ordering. Samples were characterized with a combination of high resolution microscopy, x-ray reflectivity, and grazing-incidence small angle X-ray scattering (GISAXS). Perpendicular lamellae were detected at the neutral free surface of all samples, and there were no combinations of t and Σ that drove island or hole formation. In-plane order at the top of the film (quantified through calculation of orientational correlation lengths) improved with t^n, where the exponent n increased from approximately 0.75 to 1 as Σ decreased from 0.6 to 0.2 nm^2. Out-of-plane defects such bent or tilted domains were detected in all films through detailed analysis of GISAXS data. The width of the out-of-plane orientation distribution did not follow a simple scaling law with t or Σ, but the maximum extent of disorder was observed in samples where the underlying brushes had low Σ. These studies demonstrate that weakly preferential interactions at the substrate can contribute to both in-plane and out-of-plane disorder.